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"STABILITY AND BIFURCATION OF UNSTEADY FLOW"

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Abstract

The work described herein concerns the determination of stability characteristics for time-dependent states of fluid flows or ordinary and partial differential equations in general. In particular nonlinear theories and simulations of bifurcation and stability are examined using energy methods, multiple-scale techniques and numerical procedures.

Summary

The following topics have been considered during the time period stated.

1. Stability of quasi-periodic solutions. When a time-periodic solution of a system of ordinary or partial differential equations becomes unstable, the bifurcating solution may be periodic or quasi-periodic. In the latter case, the determination of the stability characteristics leads to the analysis of a quasi-periodic linear equation of Mathieu or Hill type. Such an analysis has been performed, Davis and Rosenblat (1979), for the case when the two frequencies are close together. The method of multiple scales is used to demark the stable from the unstable parametric regions. This work was done during Prof. S. Rosenblat's visit to Johns Hopkins.

2. Bifurcation of quasi-periodic solutions. In order to understand how quasi-periodic solutions bifurcate from periodic ones, some model equations are being examined. Here we are attempting to construct the quasi-periodic branches in sets of ordinary differential equations and use multiple scale techniques to suppress certain small divisors that normally arise. This suppression is the key technical feature of the work. This problem is being tackled by graduate student P. H. Steen.

3. Energy stability decelerating swirl flows. An infinitely long circular cylinder and its contained viscous fluid are rotating as a solid body. At time $t = 0$, the container begins decelerating. Three cases of shell motion are considered: impulsive, linear and exponential. Through viscous diffusion, an unsteady flow is set up. This flow can be centrifugally unstable near the boundary. An energy stability theory (Neitzel and Davis, 1978) is set up to give lower bounds on the onset time t_o and upper bounds on the decay

time t_d. Here the onset time refers to when any instabilities present begin to grow, $t_o > 0$. The decay time $t_d > 0$ refers to when any instabilities generated by the deceleration must begin to decay to zero. Since an energy theory is used, disturbances of arbitrary amplitude are allowed. This work is part of G. P. Neitzel's Ph.D. thesis to be completed in Spring 1979.

4. Nonlinear numerical simulation of spin-down instabilities. When a liquid-filled shell (a finite length circular cylinder) moves through the air, the shell motion is slowed by the action of a drag. The resulting fluid motion is called spin-down. Here, Ekman boundary layers at the ends act as a pathway for the much augmented adjustment of the fluid motion to the new shell motion. The total flow field is axi-symmetric and unsteady. As was discussed in Section 3 above, this flow could also be centrifugally unstable leading to modified Taylor vortices which would in turn augment even further the rate of adjustment of the fluid motion to the cylinder motion. A finite-difference simulation of such instabilities is being considered. Here the Ekman boundary layers plus the side-wall layers must be resolved. The object here is to determine when such complicated three-dimensional unsteady flows become unstable, how the spin-down time is augmented by the instability, how to torque exerted by the fluid on the shell is modified, how the secondary instability flow is characterized and how the enhanced mixing might inlfuence the shell motion. This work is part of G. P. Neitzel's Ph.D. thesis to be completed in Spring 1979.

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